Transit Zones of the Solar System Planets

Wells, R., Poppenhaeger, K., Watson, C., & Heller, R. (2017). *Transit Zones of the Solar System Planets*. Poster session presented at Advanced School on Exoplanetary Science, Salerno, Italy.

Transit Zones of the Solar System Planets

Robert Wells[1], Katja Poppenhaeger[1,2], Chris Watson[1], René Heller[3]

1. Queen's University Belfast, UK, 2. Harvard-Smithsonian CfA, USA, 3. Max Planck Institute for Solar System Research, Germany

Introduction

- We have now detected over 2700 transiting extra-solar planets, but where could transits of the Solar System planets be observed?
- To answer this, we introduce the concept of "transit zones" (TZs) – regions on the sky where full transits of the Solar System planets could be observed.
- The diagram on the right shows how these zones are projected as a disk around the Sun for any given planet.
- The equation gives the "transit zone angle", i.e. the thickness of these disks, where d (Sun-planet distance) may vary throughout the orbit due to eccentricity.

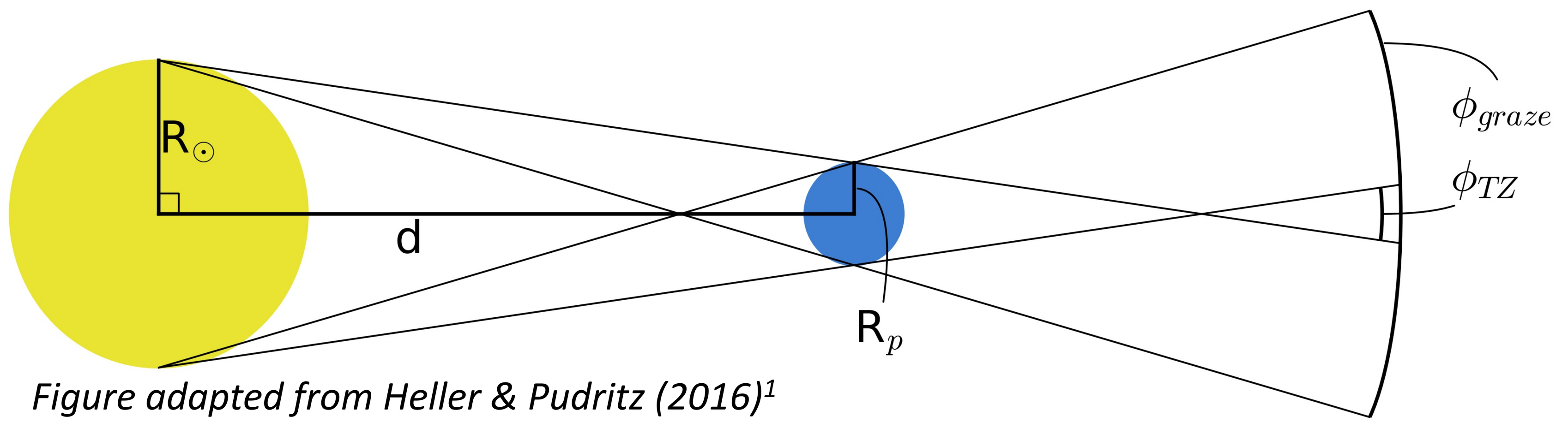


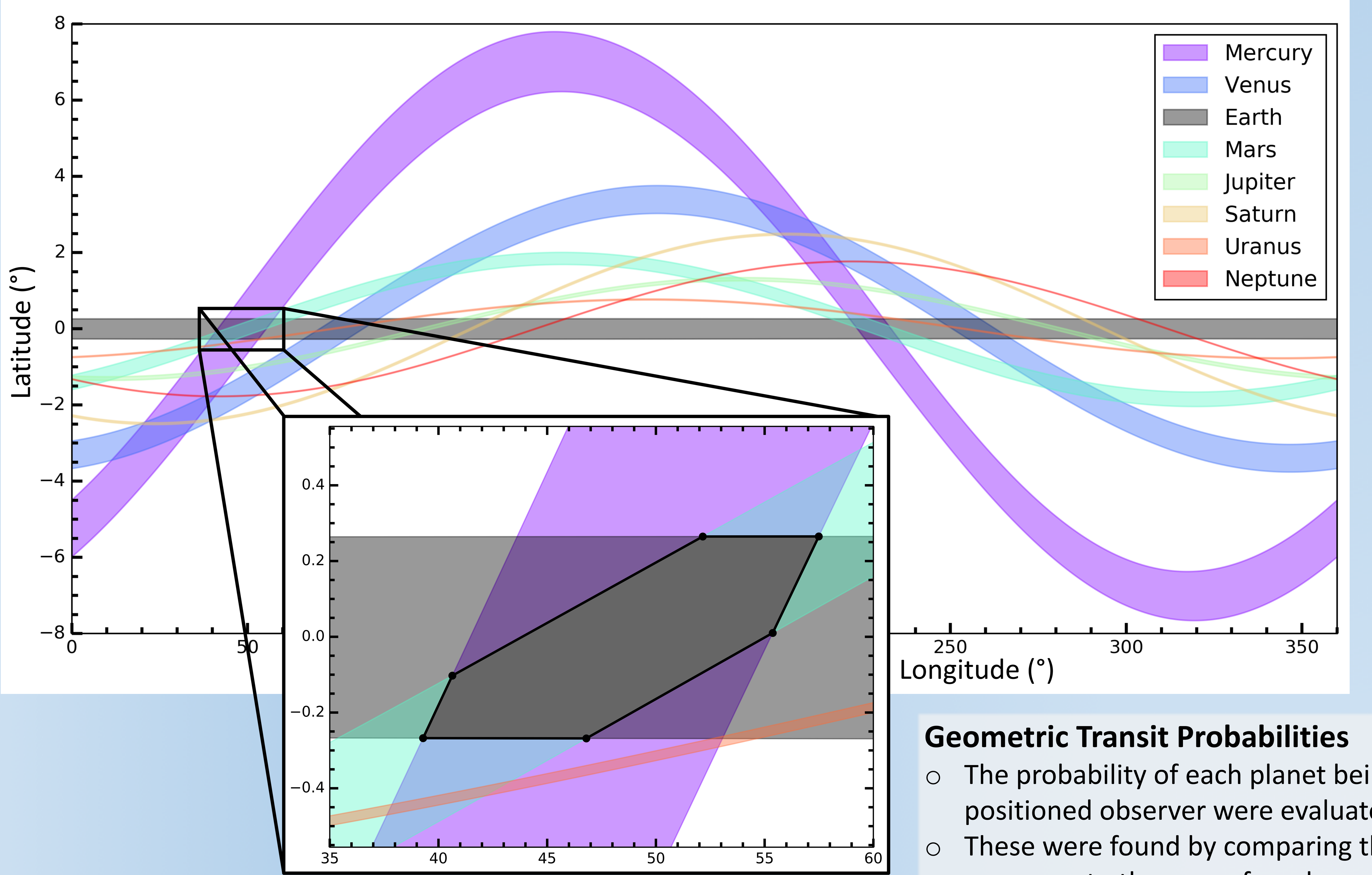
Figure adapted from Heller & Pudritz (2016)[1]

$$\phi_{TZ} = 2\left(\arctan\left(\frac{R_\odot}{d}\right) - \arcsin\left(\frac{R_p}{\sqrt{(d^2 + R_\odot^2)}}\right)\right)$$

Method

- Obtained heliocentric-ecliptic coordinates and the Sun-planet distance for 300 data points over a single complete orbit for all Solar System planets from JPL Horizons[2].
- Computed the transit zone angle at each point using the equation above.
- Computed boundaries of the transit zones by adding/subtracting $\varphi_{TZ}/2$ from the latitude at each point.

➡ These are plotted below for all transit zones, where an observer situated within a coloured region could see transits of the related planet.



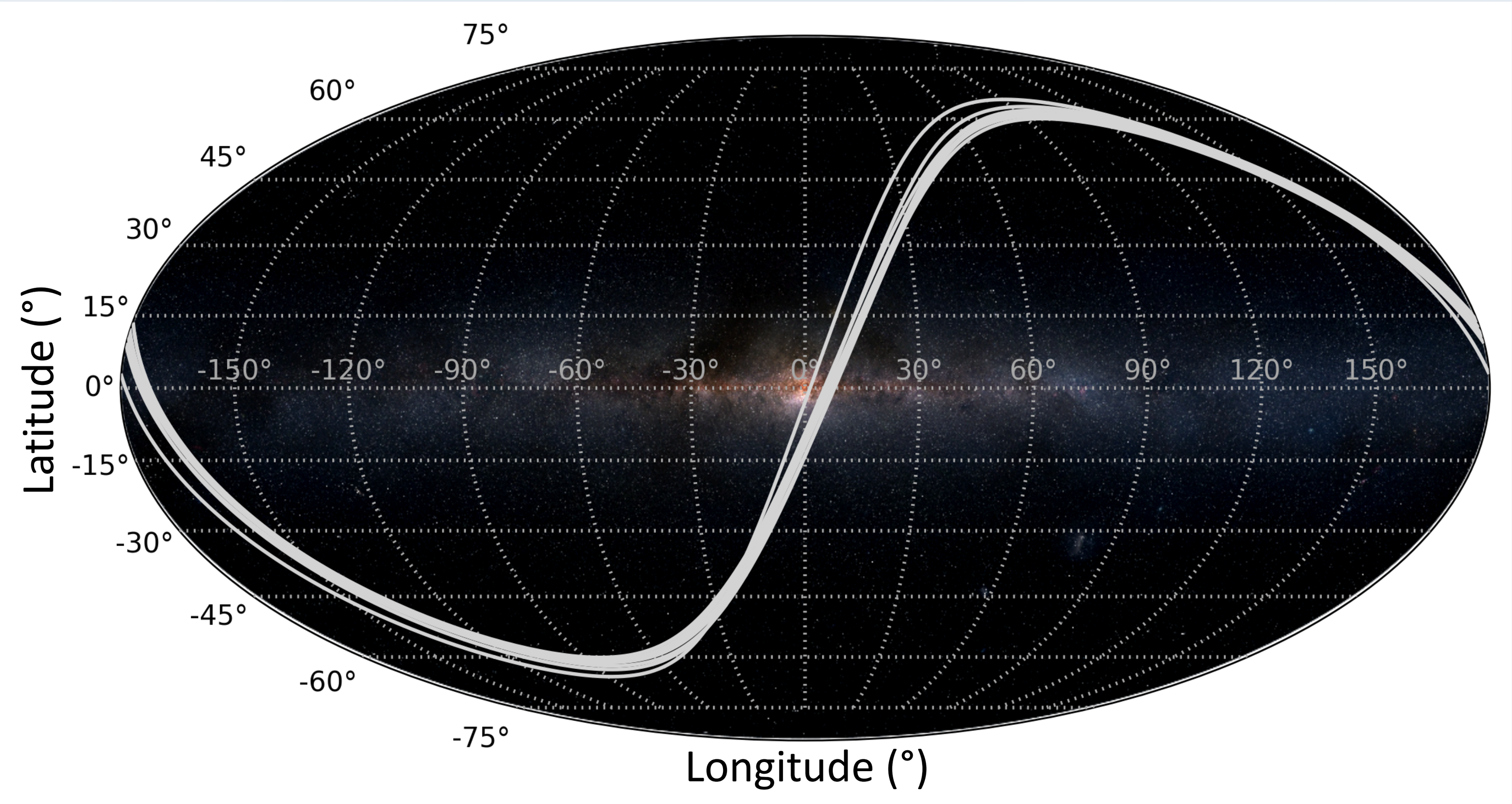
- Earth's TZ is a disk of near-constant latitude with a thickness of 0.528° centered on zero (the ecliptic plane).
- The other planets describe sinusoidal tracks.
- Only possible to view transits of a maximum of 3 planets from any point in the sky.
- All planets' transit zones cross with each other.
- 8 combinations exist where three different planet transits can be observed (see zoomed-in example)
- Each crossover consists of two regions displaced by roughly 180 degrees of longitude.

Geometric Transit Probabilities

- The probability of each planet being visible for a randomly positioned observer were evaluated.
- These were found by comparing the area of each transit zone and crossover to the area of a sphere, 4π.
- We note significant differences when approximating the transit zone angle as $2R_\odot/d$, first utilised by Borucki and Summers 1984[3].
- This approximation causes the probabilities to be overestimated by up to 17%, due to treating the planets as point object.
- We therefore note that this approximation should not be used for larger planets as it does not hold.

Transit Zones across the Milky Way

- The figure below shows how the orbits of the Solar System planets project on to the galactic plane.



Estimated no. of Earth analogues in Earth's transit zone

- From $\eta_\oplus$ – the frequency of Earth-like planets in the habitable zone around their host star, we estimate how many we would expect to find the Earth's transit zone.
- 1022 K and G dwarfs with $M_V < 13$ (PLATO limit) in Earth's TZ in the Simbad catalogue. ~3000 accounting for catalogue incompleteness.
- $\eta_\oplus$ = 22% for 0.5-1.4$R_\oplus$ around GK stars[4].
- Therefore expect 660 Earth-like planets in this sample of GK stars.
- Transiting probability of Earth = 0.46%.

➡ Expect 3 planets which transit from our perspective.

References

1. Heller, R. & Pudritz, R. E., 2016, Astrobiology 16, 259–270
2. https://ssd.jpl.nasa.gov/horizons.cgi
3. Borucki, W. J. & Summers, A. L., 1984, Icarus 58, 121–134
4. Batalha N. M., 2014, PNAS, 111, 12647

Questions or Comments?

- If I'm around, just ask!
- Or else, email me at **rwells02@qub.ac.uk**